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Evaluating Animal Agriculture Impacts on Water Quality: Data Gaps in West Central Minnesota Case Study

Ed Brands
University of Minnesota - Morris

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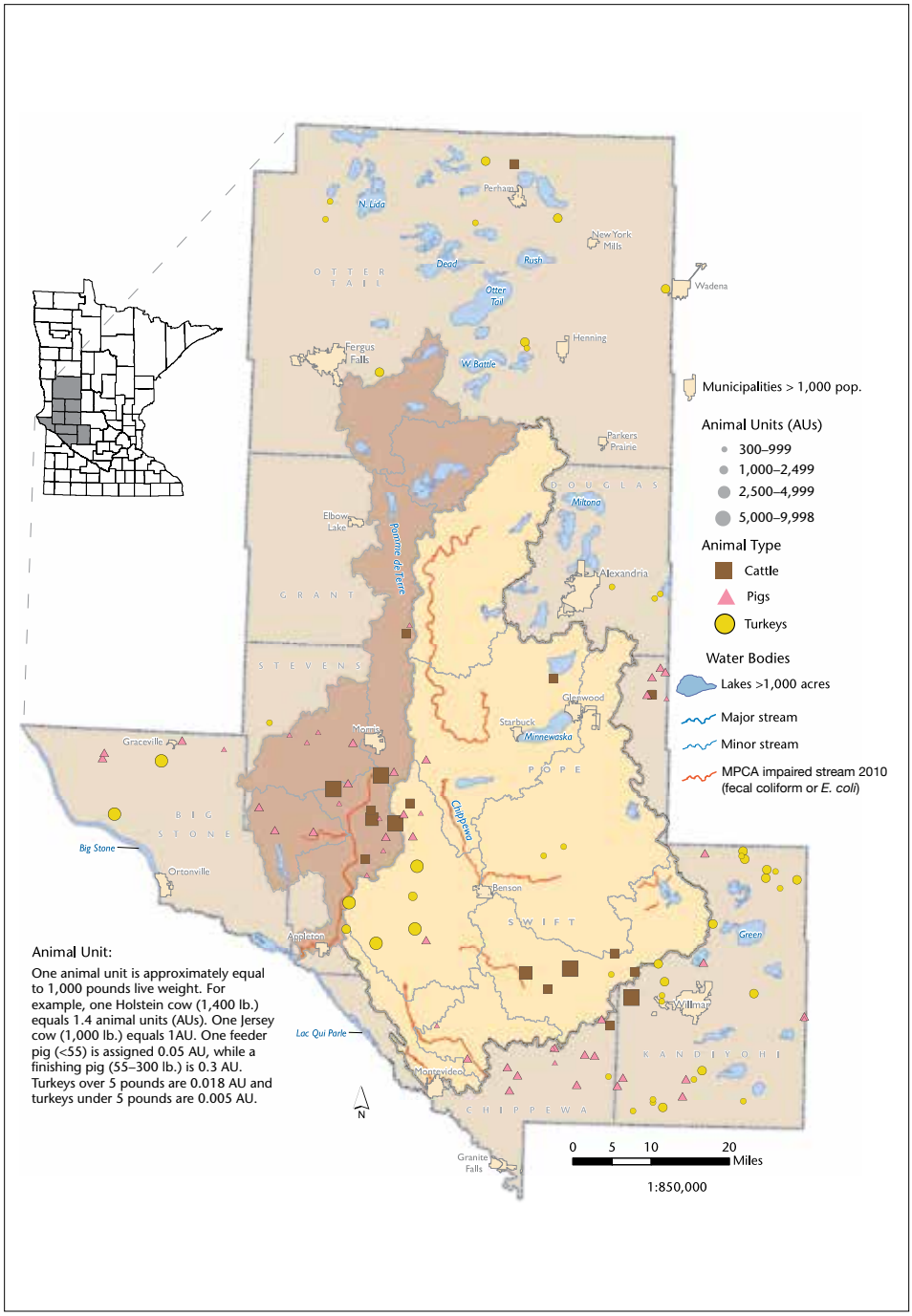
By Ed Brands

Abstract: *Balancing the economic and food system contributions of animal agriculture with negative impacts such as water quality degradation has been a recurring question in Minnesota and other agricultural states (e.g., Iowa and North Carolina). Over the past 15 years significant federal- and state-level changes in the regulation of animal feeding operations (AFOs) and associated practices have attempted to improve water quality. The impacts of these changes are unclear; therefore, the main purpose of this project was to evaluate policies designed to protect water quality from manure runoff and spills within the context of a manageable geographic area. Project work was based on manure reports and other publicly available data (2010–2011) on large AFOs in nine counties that encompass the Pomme de Terre River and Chippewa River watersheds in west central Minnesota. Based on summarizing and evaluating the completeness of annual manure reports, and an understanding of the distribution of and practices surrounding manure in the study area, it is clear that there has been progress in the form of collecting more information about manure generation and related practices, as well as keeping large AFOs farther from open water and perennial streams. However, there are still major data gaps (e.g., incomplete information about application methods, and a lack of water quality monitoring during the manure application season) that prevent more thorough evaluation of the effectiveness of manure application practices and AFO siting policies. Funding is required from the Minnesota legislature to enable the Minnesota Pollution Control Agency, local watershed groups, and producers to collaboratively address these data gaps; to compile, compare, and evaluate manure application best practices; and to revisit state policy related to siting AFOs near conduits to surface waters. The research in this article was supported by a grant from CURA's Faculty Interactive Research Program.*

Figure 1. Large Animal Feeding Operations in West Central Minnesota Counties and Watersheds



Data Sources: Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, Minnesota Geospatial Information Office, United State Geological Survey

Ed Brands

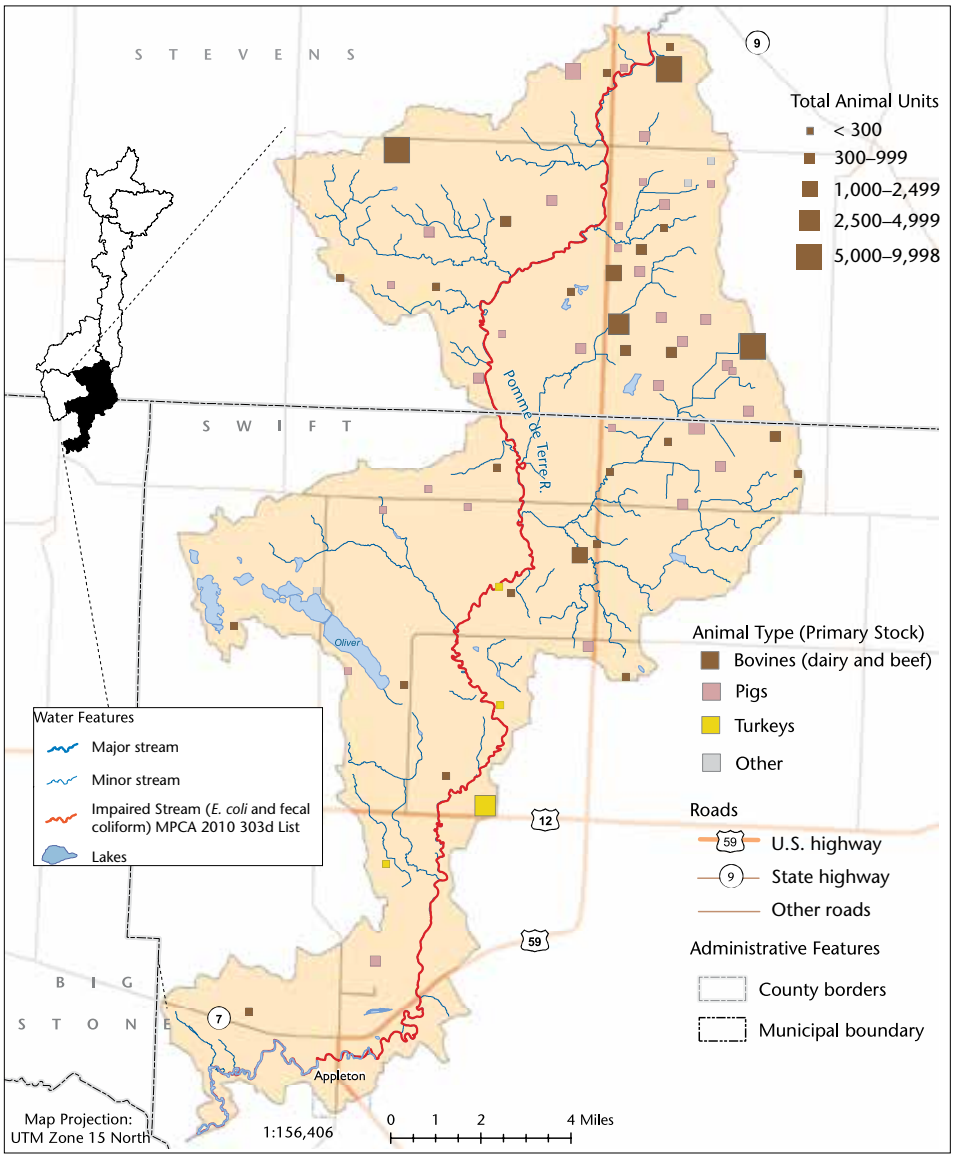
Minnesota leads the United States in turkey production, produces the third-most swine in the nation, and is home to many large dairy and beef operations. Minnesota's meat and other animal products are vital to the state's economy and are significant contributors to state, regional, national, and international commodity markets (> 10% of the pigs and turkeys raised in Minnesota are headed to international markets). But in addition to their economic contribution, large animal feeding operations (AFOs) are also associated with water quality impacts, including fish kills and elevated nutrient and fecal coliform bacteria levels. Although AFO siting restrictions, design requirements, and manure application rules and record-keeping have become increasingly stringent over the past three decades, the U.S. Environmental Protection Agency (EPA) indicates that five of the ten leading stream impairment sources were still related to animal agriculture and included grazing near streams, grazing or feeding operations, and permitted runoff from concentrated animal feeding operations. In recent decades, federal and state regulations have increasingly focused on manure application practices. One recent water quality–related requirement has been for large AFOs to submit annual manure reports to state agencies such as the Minnesota Pollution Control Agency (MPCA). A second major change in Minnesota concerns the sites where manure is generated—in 2000, the state adopted a rule prohibiting large AFO construction or expansion on shoreland. AFO siting had previously been handled by county or other local government entities.

Major Findings and Recommendations

Annual manure reports include information about the amount and types of manure generated, whether manure was used onsite or transferred, and manure application practices and timing. Of the 111 large AFOs studied in 2010–2011, 107 reported manure generation; none of the reports indicated violations of MPCA rules. Eighty-six of the AFOs reported transferring manure to other parties, and reports were most complete when the AFO owners also applied manure to their own lands. When manure was sold or transferred to others, manure application practices (rates, timing, and methods) were typically included in less than one-fourth of annual manure reports. Transferred manure accounted for nearly 80% of total manure generated by large AFOs.

The distribution of AFOs (and therefore manure generation) within the study area is highly variable. Some counties or watersheds have very few operations, whereas others have significant clusters of large AFOs (Figure 1). These large AFOs produced > 475 million gallons of liquid manure, and nearly 250,000 tons of solid manure. Nearly half (49%) of the liquid manure was generated in one county (Stevens), and three-fourths of the solid manure was generated in three counties (Kandiyohi, Stevens, and Swift). The Lower Pomme de Terre watershed covers only 153 square miles (2% of the study area) but contributed > 40% of the liquid manure and > 20% of the solid manure generated by large AFOs in the study area (Figure 2). Increasing geographic concentration of animal agriculture may be due to several factors, including rapid consolidation of the industry and clustering of integrated animal production facilities such as cow-calf-dairy operations, farrow-feeder-finish pig operations, and breeder-brooder-grower turkey operations. Another influencing factor may be county restrictions on AFO capacity, but only two of the nine counties in the study area had restrictions on the number of animal units (AUs; an AU is an animal of ~ 1,000 lb.) on a given production site: Pope (2,000) and Big Stone (3,000).

Figure 2. Animal Feeding Operations in the Lower Pomme de Terre River Watershed (2010–2011)



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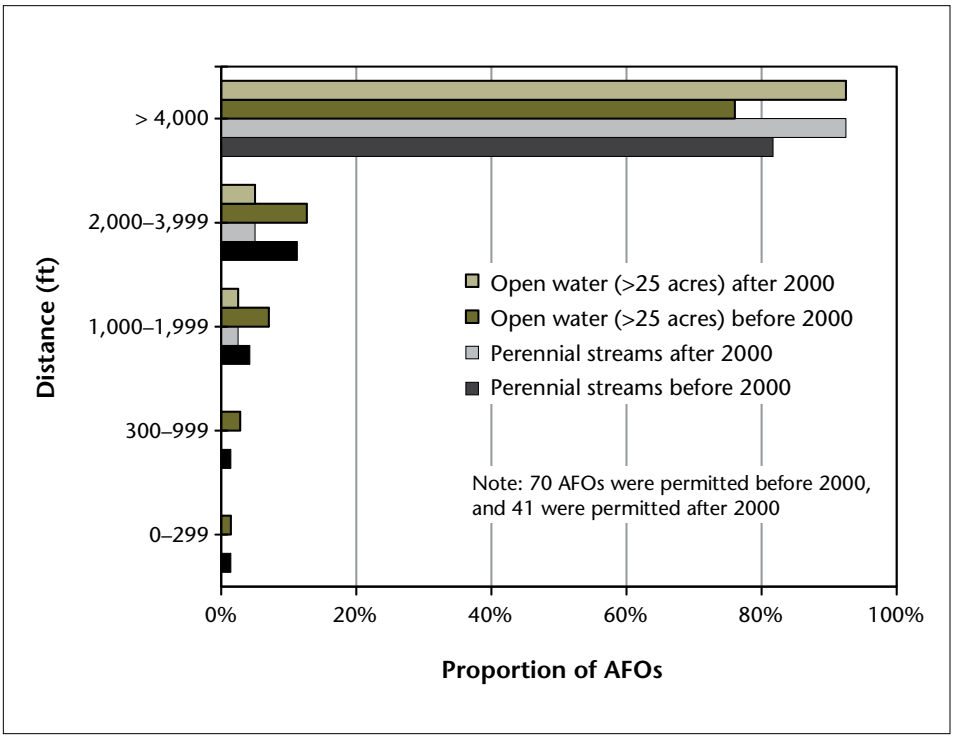
Data Sources: Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, Minnesota Geospatial Information Office, United State Geological Survey

Figure 3. Proportion of AFOs by Distance to Nearest Perennial Stream and Open Water



In 2000, the state assumed control over siting AFOs with respect to surface water bodies. Minnesota Rule 7020 was amended to prohibit construction or expansion (> 1,000 AUs) of AFOs within shoreland. Since 2000, no newly constructed AFOs in the study area were sited within shoreland and the average distance between AFOs and protected waters has increased (Figure 3). However, AFOs continued to be located near intermittent streams and drainage ditches, which in wet weather may serve as rapid conduits to perennial streams, wetlands, or lakes.

Several stream segments within both the Pomme de Terre and Chippewa River watersheds are impaired with *E. coli* or fecal coliform bacteria, and in both cases AFOs are listed by the MPCA as one of the contributing factors. Whereas the cluster of large AFOs in the Lower Pomme de Terre River watershed appears to coincide with the impaired stream segment (see Figure 2), there does not seem to be a similar pattern of association between large AFOs and impairments in the Chippewa River watershed. Given the sheer volume of manure generated by large AFOs, it seems likely that one or more AFOs are contributing to bacteria impairments.

Significant data gaps make it difficult to examine whether AFO siting or manure practices, both, or neither are associated with water quality impairments. Such gaps include incomplete manure reports, especially on transferred manure, and water quality monitoring, which typically ceases in late September, before the majority of manure is applied to fields. Manure spills may also be a significant contributor to local water quality problems, and no publicly accessible database on spills exists. In 1998, the Minnesota legislature funded a Generic Environmental Impact Statement on animal agriculture. With the subsequent implementation of EPA rules for identifying and addressing impaired surface waters in the state, much more, yet still incomplete, information on water quality is available now. Therefore, funding is required from the Minnesota legislature to update the work done for the 1998 statement and to enable the MPCA and local watershed groups to address the data gaps in manure reporting, manure spills, and water quality monitoring.

Manure and Water Quality in the West Central Minnesota Study Area. The study area of nine largely agricultural counties in west central Minnesota contains the entirety of the Pomme de Terre and Chippewa River watersheds. Landforms in the area vary considerably and range from a swath of moraine-dammed and kettle lakes, which stretch from central Otter Tail County to near Willmar, to the flat, deep-soiled former prairie dotted by shallow vegetation-dominated prairie potholes, which constitute the rest of the study area. In this latter part of the study area, < 1% of the pre-European settlement wetlands remain due to extensive and still ongoing tiling and other agricultural drainage practices.

Cultivated land is by far the dominant land use in all nine counties; however, this ranges from 47% (Otter Tail) to 87% (Chippewa). More than 10% of Otter Tail and Douglas counties are open water; whereas the remaining seven counties all have < 7.5% open water. Grassland makes up 10% or more of land cover in Otter Tail, Kandiyohi, Pope, and Douglas counties. Total maximum daily load processes are being implemented to address fecal coliform impairments in the Pomme de Terre and Chippewa River watersheds. In both cases, permitted runoff from concentrated animal feeding operations (CAFOs are large operations of 1,000 or more animals), manure runoff from fields, and animal feeding/grazing operations are listed as probable sources of fecal coliform.

Animal Feeding Operations. The current statewide distribution of AFOs and of manure production is rooted in historical trends of consolidation and concentration that have been ongoing for many decades and intensifying in the last 30 to 40 years. Data from the U.S. Department of Agriculture (USDA) Census of Agriculture illustrate the concentration of animal agriculture in Minnesota between 1974 and 2007. Numbers of cattle, pig, and turkey farms have decreased, while pig and turkey inventories have increased significantly. According to the Census of Agriculture, in 2007:

- 97% of pigs were raised on farms with 500 head or more, an increase from only 27% in 1974.
- 30% of cattle were raised on farms with 500 head or more, compared with 6% in 1974.
- Although concentrated production became standard practice much earlier in the poultry industry than with either pigs or cattle, the percentage of turkeys sold on farms with 60,000 or more birds still increased from 87% in 1974 to 96% in 2007.

Compared to changes in Minnesota from 1974 to 2007, the study area overall has lost a smaller percentage of its bovine inventory, gained proportionally fewer swine, and experienced a similarly rapid growth in turkey inventory. But these changes varied significantly by county. Virtually all of the turkey operations in the area are found in Kandiyohi, Otter Tail, and Swift counties, and most of the growth in turkey inventory occurred in these counties between 1978 and 2002. Of the 174,000-head increase in swine inventory, 128,000 were accounted for in Stevens County alone. Bovine inventory also increased significantly (56%) in Stevens County between 1992 and 2007, whereas there was either no change or a significant decrease in inventory in all other study area counties.

The majority of the large AFOs in the study area were turkey (46) and pig (47) operations, with only 18 bovine operations. More than half (58) of the AFOs had between 1,000 and 2,500 AUs, while 38 had between 300 and 999 AUs and only 12 had > 2,500 AUs. Most of the largest AFOs in the study area were located in a band from near Morris to southeast Kandiyohi County, with the highest concentration of major AFOs in the Lower Pomme de Terre watershed. All of the largest AFOs (> 5,000 AUs) were dairy operations.

Annual Manure Reports. Large AFOs are considered point sources of pollution and must obtain a Clean Water Act National Pollutant Discharge Elimination System (NPDES) permit. The MPCA implements the NPDES program in Minnesota as a part of its feedlot program. The annual manure report requirement is a recent addition to the MPCA feedlot program requirements, and 2012 was the first year that large AFOs were required to submit annual manure reports. The several reporting categories of the manure reports are discussed next.

All of the large AFOs in the study area completed an annual manure report for the October 2010 to September 2011 crop year. Four of the AFOs, one of which was under construction, reported zero manure for the year, and 107 reported some amount of manure was generated (generally liquid for dairy and swine; solid for beef and poultry). Fourteen AFOs reported generating both liquid and solid manure. Eighty percent of the AFOs reported transferring at least some of their manure to other parties. Two-thirds of the AFOs that transferred manure reported the monthly volume or tonnage of transfers; nearly 80% of liquid manure transfers occurred from late September to early November.

Seventy-nine percent of both solid and liquid manure was transferred for use by others, with the balance utilized as fertilizer on lands owned by the AFOs. Although data were incomplete, based on those AFOs that did report this information, there were three possible uses for manure:

1. the majority was applied to land for fertilizer;
2. some turkey litter (e.g., from Willmar Poultry Company sites) was combusted for electricity production at the Benson FibroMinn plant;
3. one AFO reported engaging in manure composting activities.

Less than half of the AFOs reported application dates and methods (e.g., surface broadcast, injection) of manure application. Of those that were reported, nearly 80% of field application took place from late September through early November. Knife or sweep injection was the application method used on three-fourths of the fields on which liquid manure was applied; solid manure was all applied by surface spreading with subsequent incorporation into the soil by tillage.

Distribution of Manure Generated in the Study Area. In crop year 2010–2011, large AFOs in the study area reported generating nearly 477 million gallons of liquid manure and nearly 250,000 tons of solid manure.

- Nearly half (232 million gallons, 49%) of the liquid manure was generated in Stevens County. Swift County (103 million gallons, 22%) was the only other county where > 100 million gallons were generated.
- Three counties generated three-fourths of the solid manure: Kandiyohi (70,000 tons, 28%), Swift (64,000 tons, 26%), and Stevens (59,000 tons, 24%).

Large AFOs in the Chippewa River watershed generated nearly 140 million gallons of liquid manure, or 63% of the estimated total for all AFOs in the watershed. Eighty percent of those 140 million gallons was generated in the Shakopee Creek sub-watershed, a 304-square-mile area with two large dairies (> 12,500 AUs combined) and one large pig operation (2,200 AUs). Large AFOs in the Pomme de Terre River watershed generated > 230 million gallons of liquid manure, or nearly 80% of the estimated total. Of those 230 million gallons, > 195 million gallons (84%) were generated in the Lower Pomme de Terre sub-watershed, a 153-square-mile area with three large dairies (> 28,500 AUs total) and five large pig operations (> 5,000 AUs total) (see Figure 2).

Compared to liquid manure, solid manure generation was less dominated by large AFOs. Large AFOs in the Chippewa River watershed generated > 70,000 tons of solid manure, or about 7% of the estimated total for all AFOs in the watershed. More than three-fourths of the solid manure from large AFOs was generated in the Lower Main Stem sub-watershed. Large AFOs in the Pomme de Terre River watershed generated > 58,000 tons of solid manure, or 22% of the estimated total. Large AFOs in the Lower Pomme de Terre watershed generated > 57,000 tons, or 98% of the total generated.

Water Quality Monitoring in the Study Area. Water quality impairments due to fecal coliform or *E. coli* exist along several stream reaches in the Chippewa River and Pomme de Terre River watersheds. In some cases (e.g., the Lower Pomme de Terre), these appear to be correlated with the largest concentrations of AFOs, but in others (e.g., the Chippewa River watershed) this does not appear to be the case. Total maximum daily load processes are being implemented to address fecal coliform impairments in both of these watersheds. Permitted runoff from AFOs, manure runoff from fields, and animal feeding/grazing operations are listed as among the probable sources of fecal coliform. Water quality monitoring in the two watersheds is largely conducted by two nonprofit organizations, the Pomme de Terre River Association and the Chippewa River Watershed Project. Each organization has a regular monitoring program, but both programs cease sample collection by late September or early October, which is typically when postharvest manure application begins in earnest.

AFO Siting Restrictions and Surface Water. Over the past 40 years in Minnesota, responsibility for regulating siting and expansion of AFOs near "waters of the state" has shifted between state and local governments. Minnesota Rule SW 54 (1971) prohibited the construction of new feedlots near rivers and lakes. Prior

Figure 4. Turkey Operation Sited Prior to 2000 Near Camp Lake

Virtual Earth Satellite

to 1971, local governments were responsible for all siting issues. Minnesota Rule 7020 (1978) repealed the statewide prohibition on constructing AFOs near surface waters, and land use planning was again left to counties and other local government entities, which likely encouraged the development of various local siting-related rules, discussed next. Finally, Minnesota Rule 7020 was amended in 2000 to reinstate restrictions on AFOs near public surface waters (lakes >10 acres, and perennial streams). Rule 7020 (2000) prohibits construction of new AFOs in shoreland as well as the expansion of existing AFOs in shoreland to > 1,000 AUs. Minnesota Statute § 103F.205 defines shoreland as land within 1,000 feet of a lake, or 300 feet of a river.

Based on satellite imagery, and consultation with state and county regulators, permit dates were determined and the locations of all 111 large AFOs were verified. Surface waters were split into those that are protected (perennial streams and lakes > 25 acres) by the siting restriction and those that are not. Using both ArcGIS and Google Earth, distances between AFOs and nearest surface waters were measured (see Figure 3).

Only four large AFOs permitted prior to 2000 had been sited in shoreland and most of these were turkey operations (Figure 4), and none of the large AFOs sited after 2000 were in shoreland. On average, the distance between AFOs and surface waters has increased for those facilities constructed after 2000. The average increase in distance between AFOs and public waters was statistically significant for lakes, but not for rivers. After 2000, large liquid manure-producing facilities were still being permitted within 100 feet of intermittent streams and ditches. Although this practice is legal, it is worth noting that ditches and intermittent streams may serve as rapid conduits to public waters, particularly in wet conditions, as recently happened in southeastern Minnesota, where a manure pit wall failed, sending ~ 1 million gallons of liquid manure into a ditch, two creeks, and eventually into the Root River.[1]

Improved Manure Management Practices. Although facilities producing and storing millions of gallons of liquid manure may be seen as significant pollution risks, manure production at such a scale also introduces an opportunity for energy production and experimenting with alternative manure application practices. For example, at the Riverview Dairy (~ 10,000 AUs, ~ 60 million gallons of liquid manure per year) near Morris, liquid manure is first run through an anaerobic digester to extract methane for purposes of generating and selling electricity (Figure 5). The digested manure is then moved to a solids separator, after which the solids are used as bedding for cows. Liquids are sent to a settling pond to remove residual solids and then to large storage lagoons.

Most of the liquid manure is applied as fertilizer in October via sweep injection (Figure 6). The sweep injector is attached to a pressurized flexible hose, which itself is hooked to a hard pipe and a series of pumps leading back to the storage lagoon. Injection of manure is not possible where implements must turn (i.e., headlands), and so best practices dictate these areas should be tilled prior to and after application to facilitate infiltration and incorporation into the soil. Finally, in an effort to match nutrient applications to plant needs during the growing season, a small proportion of the liquid manure is applied to corn silage during the growing season through an existing irrigation system with drop hoses that spray below the leaf canopy.

[1] Marcotty, J. Million-Gallon Cow Manure Spill Fouls Root River Tributaries. Minneapolis Star Tribune (2008). (accessed on 2.25.2014) http://www.startribune.com/local/203125981.html?refer=y

What are the impacts of these practices on water quality? Several researchers from the USDA Agricultural Research Service are currently studying field-scale impacts of fertigation on nitrate in tile drainage. However, there are few or no known watershed-scale studies of fertigation or of various manure practices in Minnesota. Many of the AFOs in the study area that reported their manure application practices indicated they used sweep or knife injection for liquid manure application. And many of the AFOs incorporated within 24 to 48 hours solid manure that was spread on the surface of fields. But we do not know how prevalent such practices really are given the incompleteness of the annual manure reports.

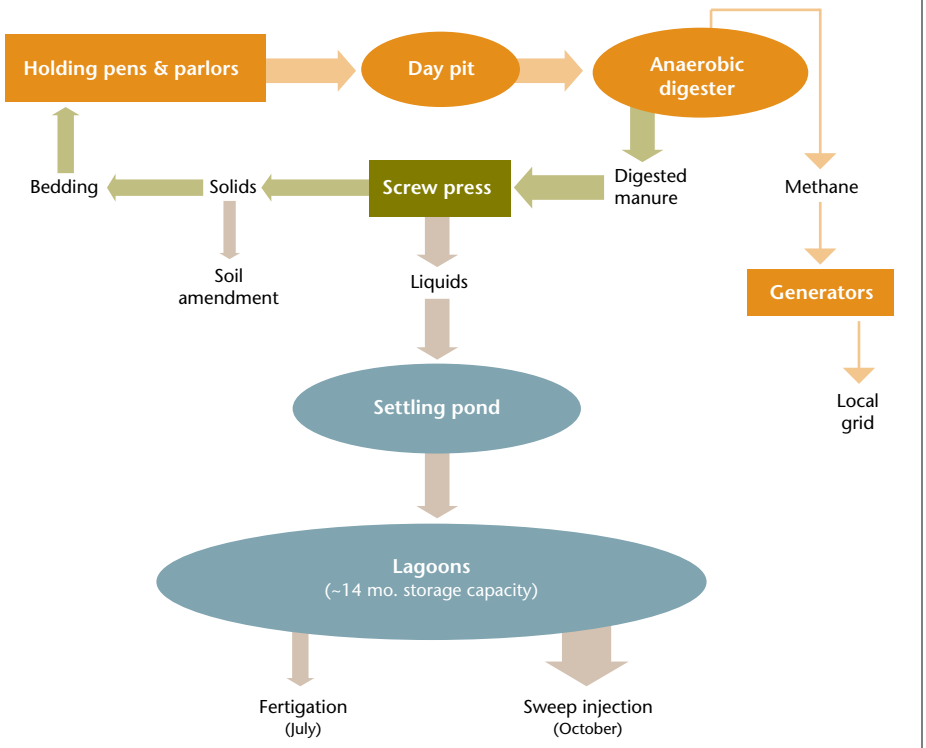
Data Gaps, Needs, and Recommendations

To combat problems associated with manure runoff from fields and from spills at production sites, more stringent manure reporting and application guidelines and siting restrictions have been put in place for AFOs. Animal agriculture appears to be continuing to consolidate, and there are often significant economic and logistical advantages to clustering several large facilities (e.g., farrow, feeder, finish) within a relatively small geographic area. With increasingly concentrated manure production, there are certainly opportunities (e.g., electricity generation) that arise from economies of scale. But the significant potential for water pollution problems makes addressing the data gaps identified in this project all the more urgent. The watershed-scale evaluation of manure management policies and associated practices is limited by three major data gaps:

1. incomplete reporting of manure application methods, timing, and rates, particularly for transferred manure, which makes up most of the manure generated by large AFOs;
2. sparse water quality monitoring efforts that often do not extend past late September and thus miss the "manuring season";
3. lack of a manure spill tracking database in Minnesota (or any other state).

In 1998, the Minnesota legislature funded a Generic Environmental Impact Statement on animal agriculture. At the time, the MPCA had only begun to implement U.S. EPA requirements to identify and create plans for addressing impaired waters in the state. Between 1998 and 2012, the number of stream reaches identified by the MPCA as impaired due to fecal coliform bacteria increased from 98 to 416. Animal agriculture is listed as a probable source of

Figure 5. Manure Cycle at Riverview Dairy, Near Morris
Manure Storage, Processing, and Energy Recovery at Riverview Dairy
http://riverviewllp.com



Note: Drawing not to scale; sizes of shapes and arrows indicate relative differences in size, flow, and capacity.

Elissa Schloesser

Figure 6. Application of Liquid Manure to Fields via Sweep Injection

Ed Brands

bacteria in many of these cases. Closing the three major data gaps noted will help improve our ability to identify, replicate, and adapt best practices, and to identify and address problems in a timely fashion.

To help improve our understanding of the relationships between AFOs and water quality, the Minnesota legislature should make available funding for the following purposes:

- Revisit and update the Generic Environmental Impact Statement.
- Enable local watershed groups to extend water quality monitoring throughout the fall.
- Enable the MPCA to construct a searchable online database that provides information to agency staff, researchers, and the public on AFOs and the generation and fate of manure, in concert with its ongoing transformation process to update its information management systems.
- Enable the MPCA (in collaboration with the Minnesota Department of Agriculture and/or University of Minnesota Extension) to study appropriate incentives (negative or positive) to producers to encourage full reporting of manure generation, storage, handling, transfer, and field application methods, dates, and rates. Currently the focus is on large AFOs, but smaller AFOs may also be contributing significantly to fecal coliform–related impairments.

The CURA-funded research in this article was also published in Environmental Science & Policy. *Read the full article at z.umn.edu/utf.*

Ed Brands is assistant professor of environmental studies at the University of Minnesota–Morris. His research centers on the science and policy surrounding water quality and animal and human waste. He teaches courses on environmental problems and policy, water resources policy, industrial ecology, and geographic information systems. Over the past 15 years, he has worked in higher education and other nonprofit and for-profit institutions on numerous projects related to water, environmental law and policy, and environmental education.